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Dental injury in general anesthesia: a comparison between direct laryngoscopy and McGRATH® VLS.

By

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Declaration

I hereby declare that, the contents and organization of this dissertation constitute my own original work and does not compromise in any way the rights of third parties, including those relating to the security of personal data.

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I would like to dedicate this thesis to Vittoria, Enrico, Nicoló Gallarato

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Abstract

INTRODUCTION

Dental injury occurs in 0.06 - 0.13 % of general anesthesia procedures requiring endotracheal intubation, and it is still a reason of complaint against anesthesiologists. Maxillary central incisors are the most common teeth injured.

OBJECTIVES:

The aim of this study is to measure the forces applied on teeth using a direct laryngoscope or a McGRATH® video-laryngoscope.

MATERIALS AND METHODS:

39 Anesthesiologists were divided into 2 groups, one of experienced anesthesiologists and the other of residents enrolled in the anesthesiology residency program of "Città della Salute e della Scienza" of Turin. Six intubations each were performed on a training manikin; three intubations using the standard intubation system with a traditional laryngoscope, and the other three using the McGRATH® video-laryngoscope in order to test the intubation forces exerted.

A force sensor (Tekscan Flexiforce® ELF system) was applied under a customized dental bite made for maintaining the pressure sensor in the correct position. This customized device was handcrafted on the dental impression of the manikin teeth in order to register any type of pressure reported on the incisal margin of the manikin`s central incisors. The forces applied were translated and measured thanks to a force acquisition system (ELF System) for real-time force measurement data acquisition.

RESULTS:

Between February 2017 and May 2017, 39 anesthesiologists were enrolled in the study. The median age was 42 (IQR 31-53).70% were experienced anesthesiologists.

There was statistically significant reduction of the forces directly applied to the maxillary incisors using the McGRATH® VLS, compared with the classic McGill blade (reduction of 11.44 Newton, 95%CI -14.33; -8.55, $p > 0.0001$)

CONCLUSION:

The use of the McGRATH® VLS during endotracheal intubation can be useful to reduce/prevent tooth damage.

In the pre-anesthesiologist visit there are certain categories of patient who have to be visited by a dentist before oro-tracheal intubation(OTI). In these categories of selected patients, the use of the McGRATH®VLS can be a viable treatment option.

Contents

Chapter 1

Introduction

1.1 Background

Damage to teeth has been associated with general anesthesia, especially to endotracheal intubation. Despite the progresses in intubation techniques, damage to teeth is still the most common cause of complaint against anesthetists. [1-8]

In literature, the overall incidence of dental trauma is 0.06 - 0.13 % of all procedures.[1, 9].

The main risk factors associated with laryngoscopy are difficult intubation and poor dental status. [1-2]

Maxillary central incisors (Fig.1/2/3) are the most common teeth injured, also because anesthesiologists might use incorrectly the superior incisors as a lever for the laryngoscope during intubation, which increases the effective impressed force. [1-3] (Fig.4)

Some procedures such as manipulative insertions, or airway obstruction may cause lesions of the oral cavity; furthermore, several authors suggested that repeated laryngoscopy can cause different events (trauma or edema of the airway mucosa) and possibly dental injury. The incidence reported in literature of troublesome or awkward intubation requiring less than or equal to two laryngoscopy attempts ranges between 1% and 18%; in particular, the incidence of difficult intubation requiring more than two laryngoscopy attempts is 1–4% and that of failed intubation is 0.05–0.35%.[2]

Other difficult scenarios for oro-tracheal intubation (OTI) include reduced mouth opening, prominent upper teeth, large tongue or other medical conditions requiring more force to be applied to the laryngoscopy blade.

The most frequent damage is the knocking out of a tooth (50%), fracture of prosthetic restorations, crowns and bridges (14%) and the dislocation and fracture of teeth (> 15%). [9, 10]

Damage to teeth happens more likely in the following circumstances due to patients' individual characteristics:

- Pathologically weakened teeth. (Fig.7/8/12/13)
- Deciduous teeth, because they have shallow roots and are prone to dislodgement.
- A number of genetic defects diseases (Fig.13) and as a consequence to drug effects abuse.

Damage to teeth may be encountered also for a combination of patients` characteristics and OTI technique:

- Poor intubation technique
- Forces applied to teeth in directions no usually encountered in daily living (e.g., lateral) by airway or suction devices, especially if the patient is uncooperative.
- the structure of teeth or their fixation. [1, 2, 7, 9, 11]

1.2 State of Art: pressure forces applied on teeth during laryngoscopy.

Bucx et al. measured the forces applied on the maxillary incisors during routine laryngoscopy with a strain gauge based sensor positioned between the handle and the blade of the laryngoscope. The results of this study clearly indicate that during routine laryngoscopy, as performed by experienced anesthesiologists, great forces are exerted on the maxillary incisor teeth(Fig.1/Fig.2/Fig.3) and there is no difference based on the operator experience [12, 13]. The straight Magill blade and curved Macintosh blade are both associated with damage to teeth(FIG.4). There are a number of modifications, particularly of the flange or vertical component, that may decrease contact with the incisors. [1, 14-17]

Difficult intubations require more force being applied to the laryngoscope blade; indeed, in case of difficult airway management, the anesthesiologist may use the upper teeth as a fulcrum if a satisfactory view of the glottis cannot otherwise be obtained.

Trauma because of excessive force or incorrect use of the laryngoscope can cause edema, bleeding, dental and soft tissue damage even when performed by skilled professionals.

Recently many authors such as Carassiti et al. described, that lower force was applied on soft tissue using a VLS (GlideScope) than a standard laryngoscope, considering the same glottis view (P=0.05). [16-18] Pieters et al demonstrated that forces exerted on maxillary incisors are lower using the video-assisted Macintosh blade laryngoscopy when compared to using a classic direct laryngoscopy [19](Fig.4) After reviewing data collection (2004-2011) on risk management cases (department of Prosthodontics and Implant dentistry CIR Dental School Lingotto-Turin) more than 30 complaints were reported, claiming damages on 10 teeth, maxillary central and lateral incisors.In all the cases referred the patients were fully reimburced and a new prosthethic rehabilitation provided (Fig.6)

1.3 Rational of this project

Based on these findings the rational of this project was to demonstrate that this new approach (VLS video-laryngoscope) with indirect view of the glottis, thanks to the use of a display, can be less risk-correlated for tooth damage instead of the use of the traditional laryngoscope. This project was conceived based on the hypothesis that the anesthesiologist can have a better control of the laryngoscope during OTI.

1.4 Figures and tables

Fig.1 Dental injury during general anesthesia.The patient was referred to the department of Surgical Science CIR Dental School, Prostodontics section (director: prof.Carossa) for tooth fracture of #21 #22 during laryngoscopy with the traditional metal blade laryngoscope.

Fig.2 The maxillary central incisors are the teeth mostly injured during general anesthesia. The mistake mostly committed during routine laryngoscopy is that the anesthesiologists use the superior incisors as a lever for the laryngoscope during intubation, which increases the effective impressed force

Here is an image of the Alveolar Bone (AB) in the pre-maxilla region. The arrows indicate the area of root breakage during traumatic tooth avulsion.

Fig.3 Root anatomy of a maxillary central incisor in a cadaveric section

Table n. 1: TOOTH DISLOCATION and subdivision

The dislocation of a tooth is divided into:

Concussion, subluxation, dislocation

Concussion and subluxation: both involve a little injury of PLD (periodontal ligament)

Concussion: a damage to tooth without displacement or increased mobility

Subluxation: tooth is mobile but not displaced

Lateral and extrusive dislocation: tooth can be dislocated in any direction

Other possible tooth damages are:

Intrusion: the apex is forced against alveolus bone, with strong compression of vascular and neural bundle

Fractures

Incomplete enamel fractures: without dental substance loss.

Uncomplicated fracture involving enamel and dentin.

Complicated enamel–dentine fracture with pulp exposition.

Root fractures: involving or not involving pulp

Avulsion: Avulsion of permanent teeth: the management and immediate treatment of an avulsed permanent tooth will determine the long-term survival of the tooth

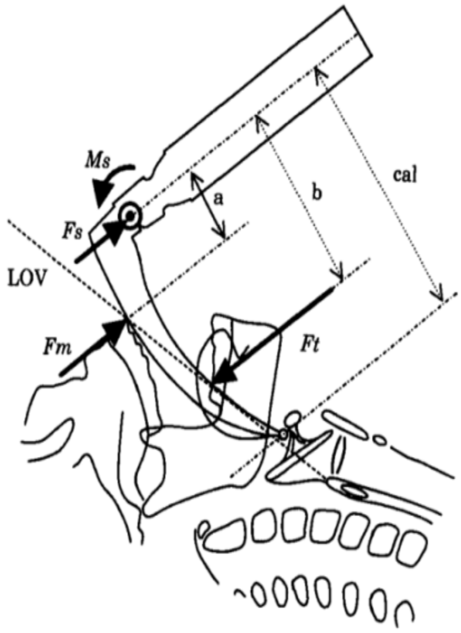


Fig.4: Biomechanics characteristics of intubation. Damage to teeth happens when the laryngoscope is used as a fulcrum if a satisfactory view of the glottis cannot be obtained.

Biomechanical model of forces during laryngoscopy: moment (Ms) and Force (Fs) are exerted by the sensor on the blade. Force is applied by the maxillary incisor teeth (Fm) on the tongue (Ft) on the blade. CAL: calibration length LOV, line of Vision; a and b, distance from the mid-point of the sensor to the application point of Fm and Ft.

Fig.5: The straight Macintosh blade

Fig.6: The Glidescope® video-laryngoscope (GVL; Verathon Inc., Bothell, USA) is a new device for oro-tracheal intubation that provides an improved view of the larynx and consistently yields a comparable or superior glottis view compared with direct laryngoscopy despite limited or lack of prior experience.

1.5 Adult patients at risk for OTI: classification.

Here are four cases showing different dental situations where the compromised /pathological dentition may affect the work of the anesthesiologist during intubation.

Fig. 7: Case number 1: patient suffering from leukemia with severe caries and fragile dentition. Any type of pressure (example during OTI maneuver) on the upper incisors may lead to crown fracture and dislodgment of fragments in the airways.

Fig.8 a-b: Case number 2: patient in orthodontic class II with devitalized teeth 11 and 21. The compromised dentition involving the two central incisors 11 and 21(visible in the OPT) makes the central incisors easily prone to damage during intubation

fig.9 a-b-c. frontal, occlusal, close up view/lateral/palatal view of case number 2: crowded dentition/ vestibular malposition and root resorption of the two central incisors are typical of patients at risk for OTI.

Fig.10: Case number 3: Patient suffering from Ameleogenesis Imperfecta causing particularly weak and fragile dentition in an adult patient.

Fig 11: Case number 4: patient suffering from severe periodontitis with teeth 11 and 21 periodontally compromised.

Fig.12: case number 5. Patient suffering from failing dentition in the upper pre-maxilla rehabilitated with a fixed bridge involving elements 12, 11, 21, 22.The periodontal condition of the upper central incisor #21 imposes particular attention during OTI maneuver for this type of patient

Fig.13: case number 6. Patient suffering from failing dentition and deep periodontal pocket affecting the right maxillary incisor (#21) .the periodontal situation affecting lateral and central incisor and the high mobility of the fixed bridge imposes particular attention during OTI.

Chapter 2

Materials and methods

2.1 Study design

An experimental, prospective study was performed from February 2017 - May 2017 on a training manikin setting for oro- tracheal intubation.

2.3 Objective

Primary Outcome:

Demonstrate that the use of the McGRATH® VLS reduces the pressure applied on maxillary central incisors of the manikin during OTI maneuver.

Two Different parameters were taken into account: the **maximum force applied** (**MFA**) which is the peak force reached during the intubation and the **average force applied** (**AFA**), which is the average force reached during the entire OTI.

Secondary Outcome

Assess the **time effectiveness(T)** for each intubation applied for the 2 different groups. Moreover **physical and personal characteristics** that could allow the anesthesiologists to get a better OTI, such as **gender** (**G**) and **level of experience (LE)** were analyzed

2.1 Anesthesiologists Selection

39 anesthesiologists were enrolled in the Center For Orthopedic Traumatology (CTO)in Torino. The selection was done dividing the anesthesiologists into 2 groups, one was composed of 28 experienced anesthesiologists and the other 11 were Residents of the anesthesiology residency program of "Città della Salute e della Scienza of Torino (CTO) None of the anesthesiologists enrolled were informed about the issue of the study.

2.3 Protocol of the study

Each participant was asked to perform 6 intubations: 3 with the standard intubation system, the other 3 intubations using the MCGRATH videolaryngoscope. In order to register the forces applied during the execution of the OTI, a pressure sensor (Tekscan Flexiforce® ELF system) was placed onto the inner surface of a customized dental bite, 1 mm thick, obtained by means of an impression of the manikin`s upper teeth : in such a way, the pressure sensor could be kept in the correct position.

2.2 Materials

In this study the experimental setting was made of :

MCGill®Laryngoscope (Fig.14) traditional laryngoscope with metal blade

McGRATH® video-laryngoscope (Fig15.): this instrument requires a brief but indispensable introduction to its use in order to understand the right method of insertion into the patient's mouth, whose anatomic structures will be displayed in the viewer and how the oro-tracheal tube should be introduced. All the operators involved, especially those who had never used a video-laryngoscope, received the basic instructions for its proper use.

TRAINING MANIKIN(FIg.16): (LAERDAL AIRWAY TRAINER) is a standard manikin for trauma training on a height adjustable stretcher.

DENTAL BITE (Fig.17)1 mm dental bite made after the manikin dental impressio(trademark ORTHORESIN DENTSPLY)is a customized plastic dental bite applied on the manikin teeth in order to mantain the pressure sensor in right position to register any type of pressure on the incisal margin of the manikin`s upper teeth during the manouver .

PRESSURE SENSOR (Fig.18)(Tekscan Flexiforce® ELF system): the sensor was glued on the internal surface of the dental bite in correspondence of teeth #11 and 21(the two maxillary incisors which are the most commonly injured teeth during laryngoscopy). The forces applied are translated and measured thanks to the transformer ELf system.

SENSOR HANDLE :(Fig.19) (Tekscan Flexiforce® ELF system): the sensor's tab is placed into the sensor handle. The handle gathers data from the sensor, processes it, and sends it to the ~~your~~ computer through a USB connection.

THE SOFTWARE (Fig.20) (Tekscan Flexiforce® ELF system): the software allows the user to view a graphical representation of the force on the sensor in real-time, record this information as a "movie," and review and analyze it later. Recorded "movie frames" can be saved as ASCII (text) files, which can be imported into a spreadsheet program, or opened in text editor or word processing program. The sensor is glued on the internal surface of the central incisors (11 and 21) in the dental bite applied on the manikin. The sensor acts as a variable resistor in an electrical circuit: when unloaded, its resistance is very high; when a force is applied (during the intubation using the two different systems) the resistance decreases and the real pressure applied during the intubation is read and transmitted.

After a simple calibration is performed, this force can be displayed on the screen in the measurement units that you choose, such as Pound or Newton.

The ELF software® is an 8-bit application that is compatible with Microsoft Windows®.

2.4 Statistical methods:

The distribution of the physicians' characteristics was summarized using frequency and percentage for **qualitative variables** and using median and interquartile range for **continuous variables**.

Differences within operators in terms of **MFA** (Maximum Force Applied) at the first attempt between the MCGRATH VLS and the traditional laryngoscopy were tested performing **paired T-Test**.

Similarly, we evaluated the differences of average force applied (**AFA**). **Stratified analyses** were performed according to gender and experience of the operators.

Finally, both univariate and multivariate linear regression were undertaken, with the maximum force applied (MFA) as the dependent variable and type of laryngoscope, order of attempts, age, gender(**G**), BMI and LE (level of experience) for each participant as explanatory variables. Statistical analyses were performed using **STATA version 13.0.**

2.4 Figures and tables

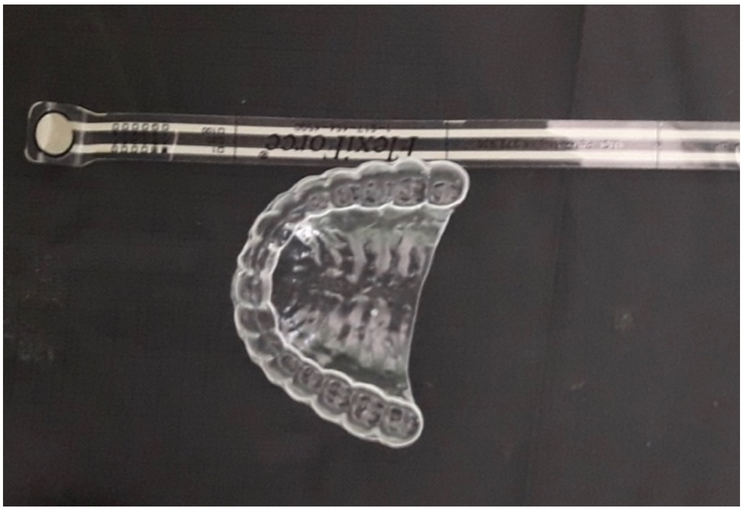
Fig.14 a-b: The traditional laryngoscope with a metal blade allowing direct intubation.The metal components of the laryngoscope makes this instrument easily sterilized.

Fig.15 a-b : the VLS Mcgrath with a video display showing the glottis and allowing an indirect intubation.

Manikin (fig16): Standard manikin (LAERDAL AIRWAY TRAINER) for trauma training on a height-adjustable stretcher.

Dental Bite (fig.17): customized 1mm thick dental bite, made of hard resin)

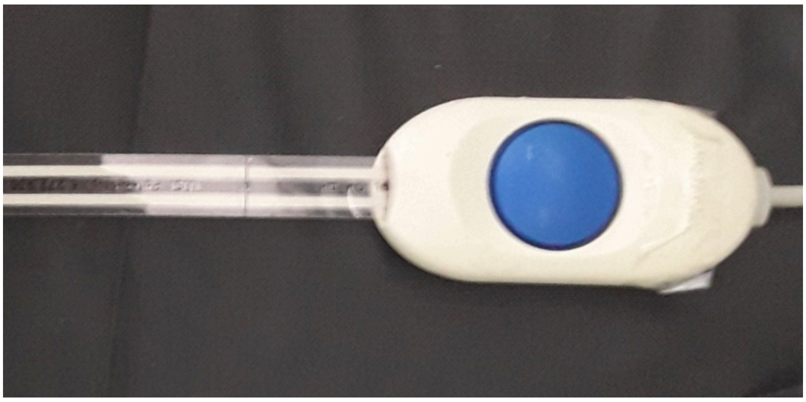
an impression of the manikin teeth and hard palate was taken with a dental silicone material (Aquasyl Dentsply) in order to realize a transparent resin dental bite (ORTHO RESIN Dentsply)



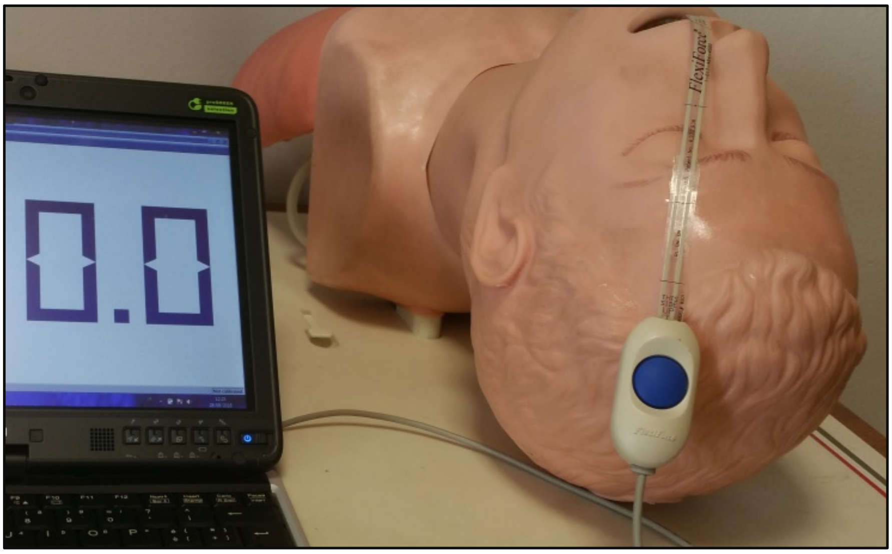
The sensor (fig.18):

The ELF sensors® use resistive-based technology.

The application of a force to the active sensing area of the sensor results in a change in the resistance of the sensing element in inverse proportion to the force applied.



Sensor Handle(Fig.19): The sensor's tab is placed into the sensor handle. The handle gathers data from the sensor, processes it, and sends it to your computer through a USB connection.



Pressure sensing system(Fig.20):

PC connected to the Flexiforce® sensor on the manikin.

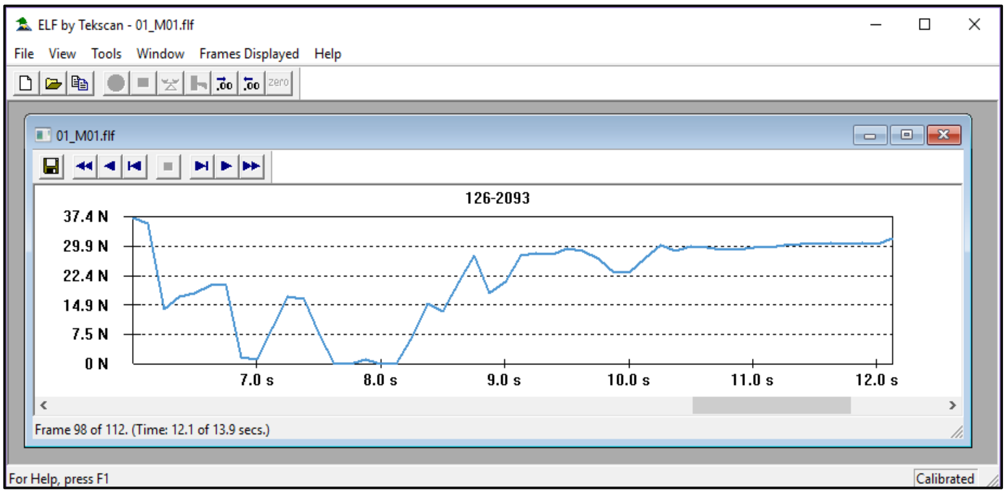


Fig 21. The ELF System® with a recording demo. Here it is possible to visualize the entire movie frame of the OTI. The 3 parameters taken into consideration were the peak force reached(MFA)/ the average force

reached (AFA) and the Time (T), which is the operator individual effectiveness for the OTI.

Chapter 3

Results

3.1 Physical Characteristics of the anesthesiologists

Between February 2017 and May 2017, 39 anesthesiologists were enrolled in the study. The mean age was 42(inter quartile range IQR) (31-53) (**table I**)

The mean age for each group was 29 years old respectively [inter quartile range (IQR): 27-31 years] and 46.5 (IQR 41.56.5). In the residents group, 81% were females and the median weight was 64 kg (IQR 52-65).

No relevant differences were observed between the two groups in terms of height, BMI, as shown in **table I**.

In particular, median years of work in experienced anesthesiologists involved was 16 years (IQR 10-28) and 71% performed 5-10 OTI /week (**table II**)

3.2 Maximum Force Applied (MFA)

As seen from **Table IV**, the maximum force applied (**MFA**) when performing intubation with the classical laryngoscope was greater than the force exerted during the maneuver performed with the McGRATH® VLS (P <0.00001).

In both groups, the peak force (MFA) recorded during classical laryngoscopy intubations is significantly higher than that recorded during VLS intubation. This is both true for the first attempt and subsequent trials. Using a statistical stratification by medical and gender role, the results obtained are comparable, with the exception of the tests performed by the "less" experienced residents. In this group, the overall MFA (using both techniques) was lower than the MFA recorded by the experienced anesthesiologists.

3.3 Average Force Applied (AFA)

As seen in **Table V**, the average force applied (AFA) during classical laryngoscope intubation was higher than the force applied during the maneuver performed with the McGRATH® VLS ($p < 0.0001$). Again, the results are overlapping both for the first attempt and for the successive ones.

Using a stratification analysis by medical and gender role, the results obtained are comparable, exception made again for the performance by the residents.

3.4 Time (T) for the entire OTI

There is no statistical evidence of differences in intubation times using the classical laryngoscopy or the McGrath video-laryngoscopy but it was clear that the repetition of the maneuver and hence the acquisition of maneuverability during the OTI training on the manikin, both with the classical laryngoscope and the video-laryngoscope, led to a reduction in intubation time (as shown in **Table VI**) in both groups.

3.5 Linear Regression Model

Detailed data are provided in **Table VII** where the effect of the two laryngoscopes were compared in a **linear regression model**. In both univariate and multivariate models the use of the video-laryngoscope was significantly associated with a reduction of 11.44 Newton in the maximum force applied (MFA) respect to the traditional device ($p<0.0001$).

According to the multivariable results, a higher force was applied by females(**G**) (+ 5.46 Newton, $p=0.002$) and by experienced anesthesiologists(**LE**) (+15.60 Newton, $p<0.0001$). A less meaningful increase of the applied force was positively associated to age and BMI, but this effect was not statistically significant.

3.6 Figures and Tables

Table I: Physical Characteristics of the anesthesiologists

	Residents (N=11)	Anesthesiologists (N=28)	Total (N=39)
Sex n (%)			
Female	9(81.12)	13(46.43)	22(56.41)
Male	2(18.18)	15(53.57)	17(43.59)
Age (years)			
average	28.72(1.95)	48.14(8.41)	42.67(11.39)
Weight (Kg)			
average	63.27(12.25)	69.67(10.76)	67.87(11.41)
Height(m)			
average	1.71(0.072)	1.72(0.08)	1.72(0.08)
BMI (Kg/m^2)			
average	21.29(3.06)	23.33(2.37)	22.76 (2.71)

Table II: Working experience of each anesthesiologist (OTI/week)

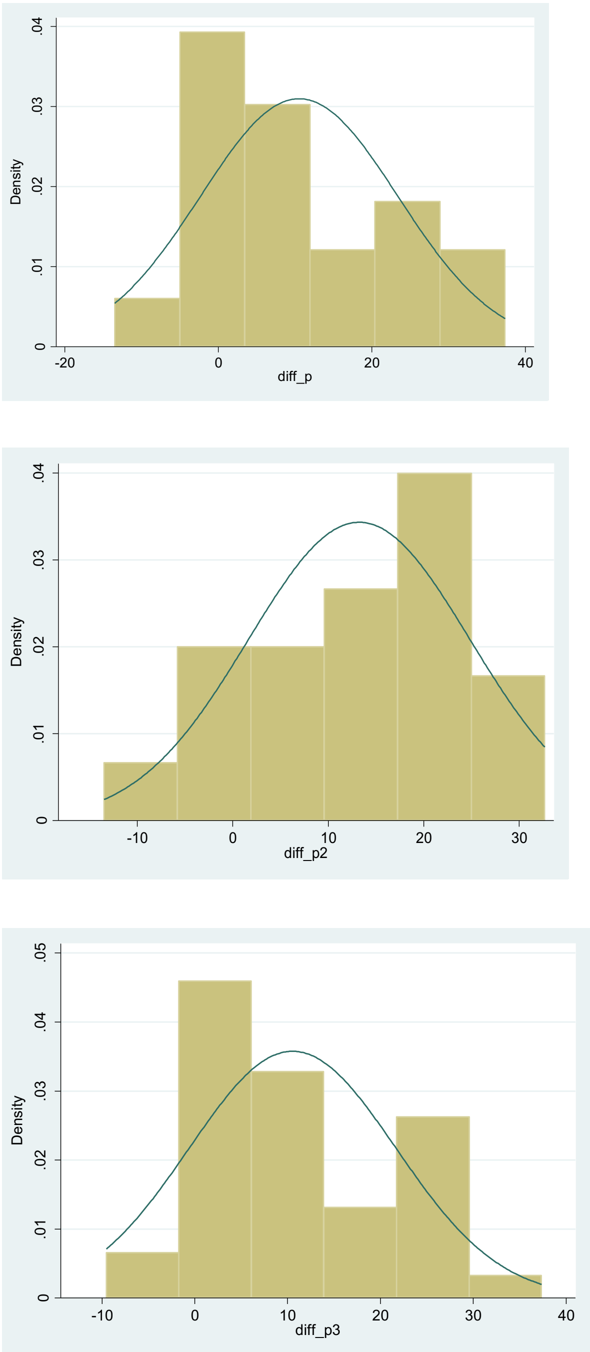
Years of working experience	
average	18.75 (9.41)
OTI/WEEK	
5-10	20(71.43)
<5	7(25.00)
>10	1(3.57)

Table III: distribution resident per year

Year of school in Anesthesiology	N(%)
I	4(36.36)
II	1(9.09)
IV	4(36.36)
V	2(18.18)

Table IV :Maximum Force Applied (MFA)

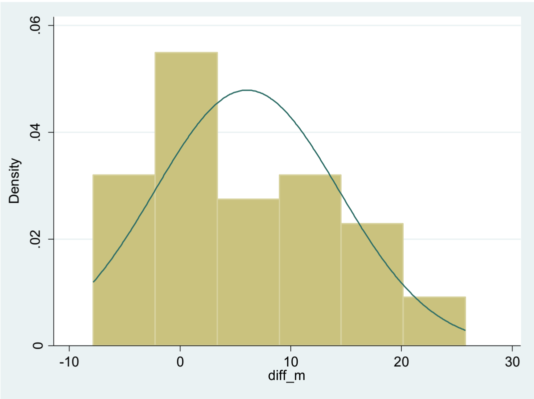
	Traditional laryngoscope(TL)	VLS	delta	p*
1st attempt				
average	24.12(13.15)	13.59(12.52)	10.53(12.87)	<0.00001
stratificated				
anesthesiologists	28.12(11.26)	15.13(12.53)	12.97(12.01)	<0.00001
residents	13.96(12.49)	9.66(12.16)	4.30(13.44)	0.3133
male (n=17)	22.22(12.48)	12.24(11.50)	9.97(12.80)	0.0054
female	25.59(13.74)	14.62(13.42)	10.96(13.12)	0.0008
2nd attempt				
average	24.52(12.54)	11.27(10.85)	13.24(11.61)	<0.00001
3 attempt				
average	21.63(13.47)	11.09(12.01)	10.54(11.15)	<0.00001

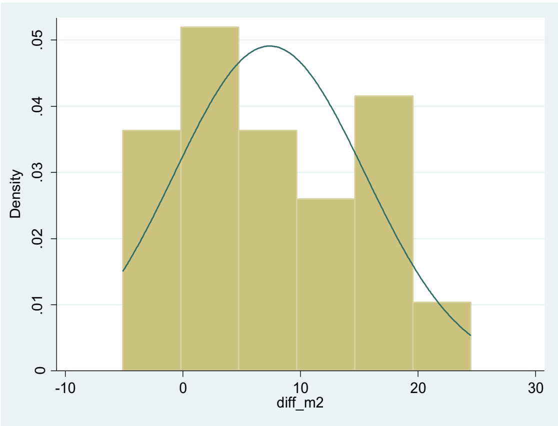


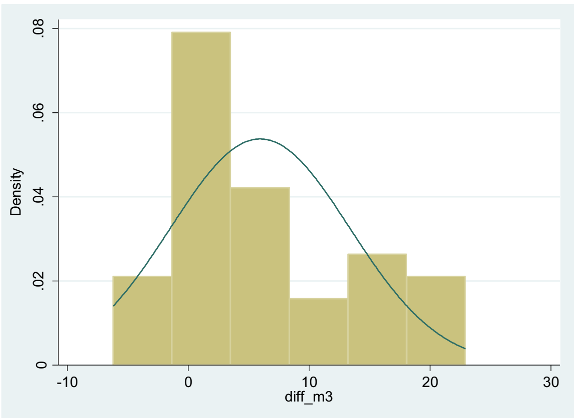
(FIG 25/26/27) Histogram of the distribution of differences between the peak forces applied to the two type of techniques (p*Skewness/Kurtosis tests for Normality)

Table V: Average Pressure Applied (APA)

	TL	VLS	delta	p*
1st attempt				
average	11.18(9.26)	5.13(6.37)	6.05(8.3)	0.0001
stratficated				
anesthesists	13.90(8.54)	5.7(6.47)	8.13(8.47)	<0.00001
residents	4.27(7.48)	3.54(6.10)	0.73(5.12)	0.6440
male(n=17)	9.09(6.7)	4.10(5.42)	4.9(6.1)	0.0042
female(n=22)	12.80(10.67)	5.93(7.04)	6.8(9.74)	0.0034
2nd attempt				
average	11.85(8.72)	4.46(5.54)	7.38(8.12)	<0.00001
3rd attempt				
average	10.91(9.09)	4.96(6.87)	5.94(7.41)	<0.00001





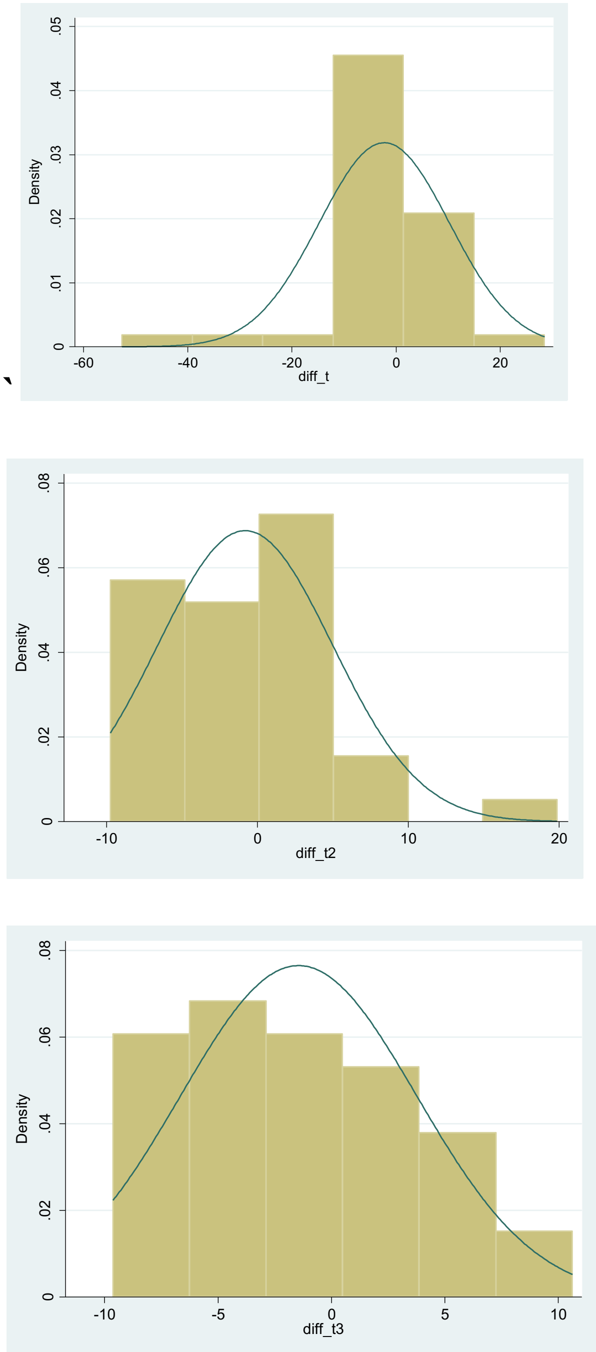


<u>(FIG.28/29/30/31) Histogram of distribution of differences of average pressure applied to the 2 techniques divided for each attempt (p* Skewness/Kurtosis tests for Normality)</u>

Table VI Time(T) for the entire OTI procedure

TL: Traditional Laryngoscope VLS: video-laryngoscope

	TL	VLS	delta	p t-test	p wilcoxon
first attempt					
average	16.04(6.99)	18.65(11.27)	2.25(12.52)	0.2688	0.2437
stratificated					
anesthesiologists					
average	15.32(5.44)	19.66(12.12)	-4.34(12.56)	0.0781	--
residents(n=11)					
average	19.14(9.71)	16.05(8.69)	3.09(11.21)	0.3820	0.0541
male (n=17)					
average	14.86(5.80)	19.44(8.90)	-4.58(8.6)	0.0448	--
female (n=22)					
average	17.59(7.70)	18.03(12.98)	-0.44(14.78)	0.888	0.769
2nd attempt					
average	12.01(4.79)	12.82(3.99)	-0.80(5.80)	0.391	--
3rd attempt					
average	9(7.5-13.12)	10.5(8.12-14.12)	-1.375(-5.62-2)		



(FIG.32/33/34) Histogram of distribution for difference in time(T) between the 2 different techniques (traditional vs VLS)

Table VII Crude and adjusted effect on MFA

In this table the effect of the two laryngoscopes were compared in a **linear regression model**.

x	**Univariate**				**Multivariate**			
	C*	SE	95%CI	p	C	SE	95%CI	p
TL	-				-			
VLS	-11.44	1.62	-14.64 ; -8.24	<0.0001	-11.44	1.47	-14.33 ; -8.55	<0.0001
Attempt								
1st	-				-			
2nd	-0.95	2.19	-5.27 ; 3.35	0.662	-9.56	1.80	-4.50 ; 2.58	0.595
3rd	-2.50	2.19	-6.80 ; 1.81	0.255	-2.49	1.80	-6.04 ; 1.05	0.167
Age	0.19	0.08	0.04 ; 0.35	0.016	-0.19	0.10	-0.340 ; 0.02	0.069
Gender: **male**	-				-			
female	3.54	1.79	0.16 ; 7.06	0.049	5.46	1.76	1.68 ; 8.93	0.002
BMI	-0.489	0.33	-1.14 ; 0.17	0.144	-0.60	0.33	-1.25 ; 0.06	0.074
L.E. Residents	-				-			
anesthesiologists	8.72	1.90	4.97 ; 12.46	<0.0001	15.601	2.67	10.34 ; 20.87	<0.0001

Chapter 4

Discussion

In this study, we investigated the difference in term of **MFA** and **AFA** between traditional laryngoscope and McGRATH® VLS.

Reviewing the results obtained the **primary outcome** was satisfied because the pressure force registered is lower in the experiments with McGRATH® VLS in comparison to the use of the traditional laryngoscope; and this effect was registered in both groups (the experienced anesthesiologists and the non-experienced residents)

Bucx et al[13] in a similar training setting evaluated that transverse forces on the maxillary incisors in 40% of the laryngoscopies reached values greater than 10 N and in 15% greater than 20 N; forces up to even 50 N were measured.

Based on these findings, the matter of which magnitude can damage the upper teeth may arise. Unfortunately, for obvious ethical reasons, few data are available on this subject. In addition, the kind of damage that these forces inflict is related to the balance between these forces magnitude, their application point and on teeth mechanical characteristics and their fixation to the maxilla.

Apart from easily visible damage that forces can inflict on teeth, such as luxation and fracture of the crown, transverse and axial forces on central incisors may also result in less easily detectable damage, resulting from only slight displacement. This may lead to damaging the neurovascular bundle that enters the tooth at the apical foramen and will result in loss of sensibility of that tooth, which will be permanent when the bundle is ruptured and the dental pulp becomes necrotic [13].

This dental damage mechanism does not seem to have been fully understood in the anesthesiologist literature. In contrast, in dental traumatology this mechanism is well known and it is reported that in

17% of traumatic injuries with no directly visible tooth damage of the dental pulp will become necrotic. In certain patients, a tooth denervation may not be immediately recognized and it is unlikely that when finally confirmed, its origin will be traced back to the laryngoscopy. Although the amount of force needed to inflict this type of damage is unknown, it will certainly be less than the amount of force needed to produce the easily detectable damage. It seems, however, reasonable to state that transverse forces greater than 10-20 N, especially in patients with periodontal disease, restored teeth or shallow roots may result in dental morbidity and that the lowest forces possible should be applied on these teeth [13]. Our study provided results in accordance with those provided by Bucx et al that forces with the use of the traditional laryngoscope can reach more than 20 N peak (MFA)force which can be considered as the limit for tooth damage.

While the use of VLS has barely reached 20 N as a peak force and thus statistically reducing the impact on noble structures such as teeth in a manikin setting.

Based on our findings, the use of the video-laryngoscope was significantly associated with a reduction of 11.44 Newton in the maximum force applied (MFA) respect to the traditional device ($p<0.0001$). We can therefore assume that the McGRATH® VLS reduces the possible teeth damage on maxillary central incisors.

As a **secondary outcome**, **time(T)** of the OTI is reduced between the first and the last trial suggesting a training effect of the operator. At the end of the three attempts, for each instrument, both the anesthesiologists and the residents spend less time in the maneuver, but the less experienced residents**(LE)** registered a lower applied force in both the peak force (MFA) and average force (AFA). Therefore, it can be assumed that intubation training technique can be useful in acquiring greater manual ability of the correct use of the video-laryngoscope. According to the results obtained through the linear regression model, it was possible to observe a higher force on maxillary incisors applied by **female anesthesiologists (G)**. This data might be used for further investigation.

4.1 Limitations of the study

Firstly, the entire system and sensor has been calibrated to bypass the force, though minimal, impressed by the plastic dental bite on the sensor between this and the teeth. However, at the time of recording the system had a force equal to 0 Newton. The sensor has been positioned on the upper surface incisor (11 and 21) on the teeth which, in most cases, are the most affected teeth during oro-tracheal intubation. Human tissues, however, are different from those of the manikin and resist differently to pressure forces.

Secondly, the manikin's teeth, made of resin, are obviously different from the human ones, these are less rigid and have a more linear behavior under pressure forces (enamel/ dentin/the PDL tend to break more easily). Human teeth are more variable regarding both size and position and can be affected by different diseases as mentioned in the introduction (fig 6/7/8/9)

Moreover OTIs were performed in sequence: the manikin was repositioned in the original neutral position at each maneuver, so that the operator would begin each intubation from the same initial position.

This has allowed us to minimize the bias on the timing of the intubation and their recordings; but it exposed us to different bias concerning the different intubation techniques and different approaches to the manikin. In the real scenario, the patient who needs to be intubated has many more difficult situations, such as the head, hyper extension of the neck, manual opening of the mouth etc.

Finally, the impossibility of masking the type of laryngoscope and the absence of randomization could generate a bias that was corrected through evaluation in the first attempt and by stratified analysis for role and gender.

Stratification of the collected data has allowed us to observe how the residents performed the OTI with less force either by using the classical laryngoscope or the video-laryngoscope. This element may suggest that residents use a better intubation technique the reason of this result may be a consequence of continuous training and because part of the specialists' training is the OTI intubation: the specialists who participated in the study, in fact, attended the operating rooms more than many structured anesthetists involved in the study.

4.2 Clinical advantages and disadvantages of the McGRATH® VLS.

The VLS is considered a sort of a new device for OTI in the anesthesiologist field. It provides an improved view of the larynx and consistently yields a comparable or superior glottis view compared with direct laryngoscopy despite limited or lack of prior experience with the device [16-18]. Despite the main advantages of this device one of which can be to have less risk for dental trauma during intubation, there are some disadvantages such as the higher costs (the VLS is provided with a disposable plastic blade which cannot be sterilized instead the traditional laryngoscope can be entirely and easily sterilized) or the possibility that unexperienced anesthesiologists have to face an OTI with this new device during emergency intubation.

Chapter 5

Conclusion

The MCGrath VLS is a less damaging and invasive instrument for avoiding excessive forces over the incisal margin of central incisors. Moreover it can be considered a better treatment option for avoiding excessive forces to other noble oral structures such as tongue and pharynx .

There are certain categories of patients where the use of MCGrath VLS should be highly advocated(fig.7/8/9/10/11/12)

In these selected categories of patient, a complete dental chart with periodontal and restorative assessment should be filled in, associated with a radiographic assessment made by a SERE (systemic endoral radiographic examination) and OPT (orthopantomography).

The dentist might help the anesthesiologists by guiding them, in order to ensure the most suitable choice of laryngoscope (traditional or VLS) in risky and uneasy patients.

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